COSEWIC
Assessment and Update Status Report

on the

Banded Killifish
Fundulus diaphanus

Newfoundland Population

in Canada

SPECIAL CONCERN
2003

COSEWIC
COMMITTEE ON THE STATUS OF
ENDANGERED WILDLIFE IN
CANADA

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AU CANADA

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This report covers only the Newfoundland population. Other populations of this species occur on the mainland in Nova Scotia, New Brunswick, Quebec, Ontario and Manitoba. Mainland populations were listed as not at risk in April 1989.

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Banded Killfish — *Fundulus diaphanus* (from Scott and Crossman (1973) by permission).

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COSEWIC
Assessment Summary

Assessment Summary – May 2003

Common name
Banded killifish (Newfoundland population)

Scientific name
Fundulus diaphanus

Status
Special Concern

Reason for designation
The population is separated from others by a major barrier to movement, i.e. 200 km of ocean. Newfoundland populations have a very limited area of occupancy. The possibility of range expansion is limited by steep gradients and impassable rapids and/or falls. Habitat degradation resulting from proposed logging would negatively impact populations in some areas.

Occurrence
Newfoundland-Labrador

Status history
Last assessment based on an update status report.

COSEWIC
Executive Summary

Banded Killifish
Fundulus diaphanus
(Newfoundland population)

Species Information

The Banded Killifish, *Fundulus diaphanus* (Lesueur 1817) is a member of the family Fundulidae (Nelson 1994). This species is one of only two members of the *Fundulus* genus found in Newfoundland, the other being the mummichog, *F. heteroclitus*. The Banded Killifish is described as having olive colored sides with numerous vertical bands and a contrasting dark coloration across the dorsal region. The vertical bands give rise to the common name "Banded" Killifish.

Distribution

The Banded Killifish is found in southeastern North America from Montana east to the Maritimes and south to south Carolina. In Canada, it is widely distributed in the Maritimes (but only from a few sites in Newfoundland) and also in suitable habitat of the St. Lawrence River valley of Quebec, through the Great Lakes watershed of southern Ontario to Lake Superior (Scott and Crossman 1973). A disjunct population is also found in Manitoba (Stewart-Hay 1954).

There are 7 known populations of Banded Killifish on the island of Newfoundland. The majority of these populations are clustered on the south and western coasts of the province. One of the most recent records of this species, from Indian Bay watershed (Backup and Third Ponds) on the northeast coast of the island is further east than previous records for this species. Initially, *Fundulus diaphanus* was only recognized from the very southwestern corner of Newfoundland in the Stephenville Crossing area. From 1980-1990, in addition to the Indian Bay occurrence, new population records include Freshwater Pond and the Rush Ponds (Winterland) on the Burin Peninsula, Ramea Island off the south coast, Loch Leven, and First Pond in the Grand Bay West area, near Port aux Basques.

The status of this species in Canada was first considered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 1989. Newfoundland populations were considered to be the biogeographically isolated from mainland populations and were assigned a status of Special Concern due to the limited area of occupancy, limitation of potential for range expansion and potential threats from logging and other activities leading to habitat degradation.

Habitat

Banded Killifish in Newfoundland depend on clear water, warm water temperatures for spawning, and dense submerged aquatic vegetation with a sandy or muddy substrate. This type of habitat is abundant throughout most watersheds in Newfoundland but the species is only found in a few of these watersheds. In addition, in watersheds where Banded Killifish occur and where there are many lakes with appropriate habitat areas, *Fundulus diaphanus* is often found only in very restricted areas within one or two lakes. Future research priorities should concentrate on habitat selection and use. Decline in this species in the future would likely be caused by habitat degradation and wetland drainage.

Biology

Newfoundland Banded Killifish grow to an average length of 73-92mm and live to a maximum of 3-4 years of age. Maturity is reached at an age of 1+ years and at a length of approximately 6cm. Banded Killifish practice external fertilization and females lay eggs equipped with adhesive threads that adhere to plants, leading to them being labeled plant-spawners. Spawning occurs in July and August at water temperatures of 19-24°C (Chippett *In prep.*).

Population Sizes and Trends

Fundulus diaphanus populations in Newfoundland occur over a wide range, but local populations are restricted to very confined regions within their respective watersheds. Banded Killifish populations in Newfoundland appear to be locally abundant in representative populations that were sampled. Although yearly data is not available, population estimates indicate that over 20,000 individuals exist in the Indian Bay watershed population on the northeast coast. Population estimates are not available for other populations.

Limiting Factors and Threats

Any disturbance, whether natural or anthropogenic, on the southwest coast of Newfoundland, could have a devastating impact on this species due to the cluster of populations in that region. However, direct threats are not perceived in this region at this time. However, forestry practices in the Indian Bay watershed may impact on the population in that area in the next few years as much of the forest in this area is scheduled to undergo some form of clear cutting.

Suitable habitat is present island-wide but inland areas are restricted from immigration of Banded Killifish by rivers with steep gradients and other barriers to inland migration.

Special Significance of the Species

Fundulus diaphanus is the only freshwater fish of special concern in Newfoundland and represents this species at the eastern extent of its range. Clustered in very localized regions of the watersheds in which they occur, Banded Killifish, which rely on the invertebrate community for food, clear water for prey selection, and dense stands of macrophytes for reproduction, are an easily studied indicator species candidate for various measures of ecosystem integrity. Banded Killifish are also important forage fish for brook trout, Atlantic salmon and American eels and form portions of the diet of various waterfowl.

Existing Protection or Other Status

The Newfoundland populations of Banded Killifish are currently listed as a species of special concern by the Committee on the Status of Endangered Wildlife in Canada. In addition, *Fundulus diaphanus* is one of 20 species protected under the Newfoundland and Labrador provincial government's Endangered Species Act passed in August 2002. Aside from this protection, the only other protection is made available through the Federal Fisheries Act. The population at Grand Bay West may be included in an ecological reserve being proposed by the Parks and Natural Areas division of the Government of Newfoundland and Labrador and the Rush Ponds population on the Burin Peninsula is an Eastern Habitat Joint Venture site.

Summary of Status Report

Banded Killifish populations in Newfoundland are very fragmented in nature. In spite of 7 known population locales, the area of occurrence of these populations is less than 200 km^2. These populations, with the exception of the Indian Bay watershed population, are clustered in relative close proximity on the southwestern portion of Newfoundland, maximizing the potential of natural disturbance, urban expansion, and industrial development, on 4 of the 7 recognized Newfoundland locales. The three populations surveyed directly (Indian Bay, Loch Leven, and Freshwater Pond) indicate that the species is locally abundant but actual population estimates are only available for the Indian Bay population.

The other major limiting factor impacting *F. diaphanus* in Newfoundland is rivers with steep gradients and other obstructions to inland migration. Habitat, in terms of substrate type and aquatic vegetation, is abundant in central regions, but is likely inaccessible to Banded Killifish due to these difficult migration routes.

The obvious habitat requirements associated with Banded Killifish throughout North America are not limiting factors in Newfoundland. However, habitat selection and use is still not fully understood and warrant further study.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) determines the national status of wild species, subspecies, varieties, and nationally significant populations that are considered to be at risk in Canada. Designations are made on all native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fish, lepidopterans, molluscs, vascular plants, lichens, and mosses.

COSEWIC MEMBERSHIP

COSEWIC comprises representatives from each provincial and territorial government wildlife agency, four federal agencies (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biosystematic Partnership), three nonjurisdictional members and the co-chairs of the species specialist groups. The committee meets to consider status reports on candidate species.

DEFINITIONS

Species	Any indigenous species, subspecies, variety, or geographically defined population of wild fauna and flora.
Extinct (X)	A species that no longer exists.
Extirpated (XT)	A species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A species facing imminent extirpation or extinction.
Threatened (T)	A species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A species of special concern because of characteristics that make it particularly sensitive to human activities or natural events.
Not at Risk (NAR)**	A species that has been evaluated and found to be not at risk.
Data Deficient (DD)***	A species for which there is insufficient scientific information to support status designation.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.
** Formerly described as "Not In Any Category", or "No Designation Required."
*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list.

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Update
COSEWIC Status Report

on the

Banded Killifish
Fundulus diaphanus

Newfoundland Population

in Canada

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2003

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SPECIES INFORMATION

Name and Classification

Class:	Actinopterygii
Order:	Cyprinodontiformes
Family:	Fundulidae
Genus:	*Fundulus*
Scientific Name:	*Fundulus diaphanus* (Lesueur 1817)
Common Name:	Eng. - Banded killifish Fr. – fondule barré

Description

The Banded Killifish, *Fundulus diaphanus* (Lesueur 1817) is a member of the family Fundulidae containing 5 genera and approximately 48 species (Nelson 1994). Sometimes referred to as egg-laying toothcarps, adult killifish are usually small, reaching between 5-10 cm in length. The largest known killifish of the family Fundulidae, *Fundulus grandissimus*, have been found to measure 18 cm (Berra 1981). Many killifish are slender and pike-like in shape to aid in rapid swimming (Riehl and Baensch 1991) and some species have a flattened head and terminal mouth adapted for surface feeding, hence the name topminnows (Leim and Scott 1966; Scott and Crossman 1973; Houston 1990). Three species of the family Fundulidae, *Fundulus diaphanus*, *F. heteroclitus*, and *F. notatus* have been recorded in Canadian waters (Houston 1990). Of these three, only *Fundulus diaphanus* and *F. heteroclitus* are found in Newfoundland (Scott and Crossman 1964,1973; Houston 1990).

Fundulus diaphanus, the Banded Killifish, is described as having olive colored sides with numerous vertical bands and a contrasting dark coloration across the dorsal region. The number of bands anterior to the dorsal fin are useful as a means of determining the sex of live fish as a greater number of "anterior" bands (approximately >9) are evident in male Banded Killifish. Bands in females usually appear black in color, are thin and distinct, and often do not appear to span the full width of the body. Males, however, have pale, grey bands that are less distinct and closer together. Figure 1 provides an illustration of a Banded Killifish.

Figure 1. Illustration of the Banded Killifish (from Scott and Crossman (1973), by permission).

Fundulus diaphanus is distinguished from *F. heteroclitus* by having a relatively thin caudal peduncle, larger gill rakers, usually numbering 5 or 6 (9-11 in *F. heteroclitus*), and having brachiostegal rays most often numbering 6,6 (5,5 in *F. heteroclitus*) (Scott and Crossman 1973). *Fundulus heteroclitus* is also most often associated with brackish waters whereas *F. diaphanus*, although euryhaline, is usually found in fresh water (Houston 1990).

Fundulus diaphanus (Lesueur, 1817) is divided into two subspecies; *Fundulus diaphanus diaphanus* (Lesueur), the eastern Banded Killifish, and *F. d. menona* (Jordan and Copeland), the western Banded Killifish. The eastern Banded Killifish differs from the western subspecies in several ways including a more anterior positioning of the dorsal fin, a greater number of anterior bars in males (9-15 *diaphanus* vs. 5-0 *menona*) and more intense bars along the side that remain intact over the anterior back, a greater number of scale rows (45-49 *diaphanus* vs. 40-44 *menona*), and a combination of dorsal dorsal and anal fin rays totaling 24 to 26 (23 to *24 menona*), as well as being much larger in size (110mm maximum *diaphanus* vs. 74mm maximum *menona*) (Trautman 1957; Hubbs and Lagler 1974). The eastern form occurs in the Atlantic drainage west to the Upper St. Lawrence and eastern Lake Ontario where it intergrades with the western form (Scott and Crossman 1973).

DISTRIBUTION

Global Range

Fundulus diaphanus occurs in North America from South Carolina in the southern United States northward to the Maritime provinces and Newfoundland in Canada, west through the states of New York, Pennsylvania, and southern Canada in the Great Lakes region as far west as the Yellowstone River in eastern Montana (Scott and Crossman 1973; Houston 1990). Figure 2 shows the distribution of *Fundulus diaphanus* in North America.

Canadian Range

Fundulus diaphanus is widely distributed in the Maritimes and also in suitable habitat of the St. Lawrence River valley of Quebec. In the Great Lakes watershed, Gilbert and Shute (1980) indicate records in all areas surrounding Lake Michigan, with most concentrated in the area northeast of the lake, numerous records along the western side of Lake Huron, few records (<10) on the eastern side, at least three records from southeastern Lake Superior, and records in both the northern and southern regions surrounding Lake Erie. In Ontario, the species was also reported from the Lake of the Woods in the northwestern portion of that province in 1986 (K. Stewart, pers. comm.). Gilbert and Shute (1980) describe the St. Lawrence River and the western New York and eastern Ontario drainages of Lake Ontario as the area of integradation between the *diaphanus* (eastern) and *menona* (western) subspecies. The western extent of the range of this species in Canada is Manitoba, where two

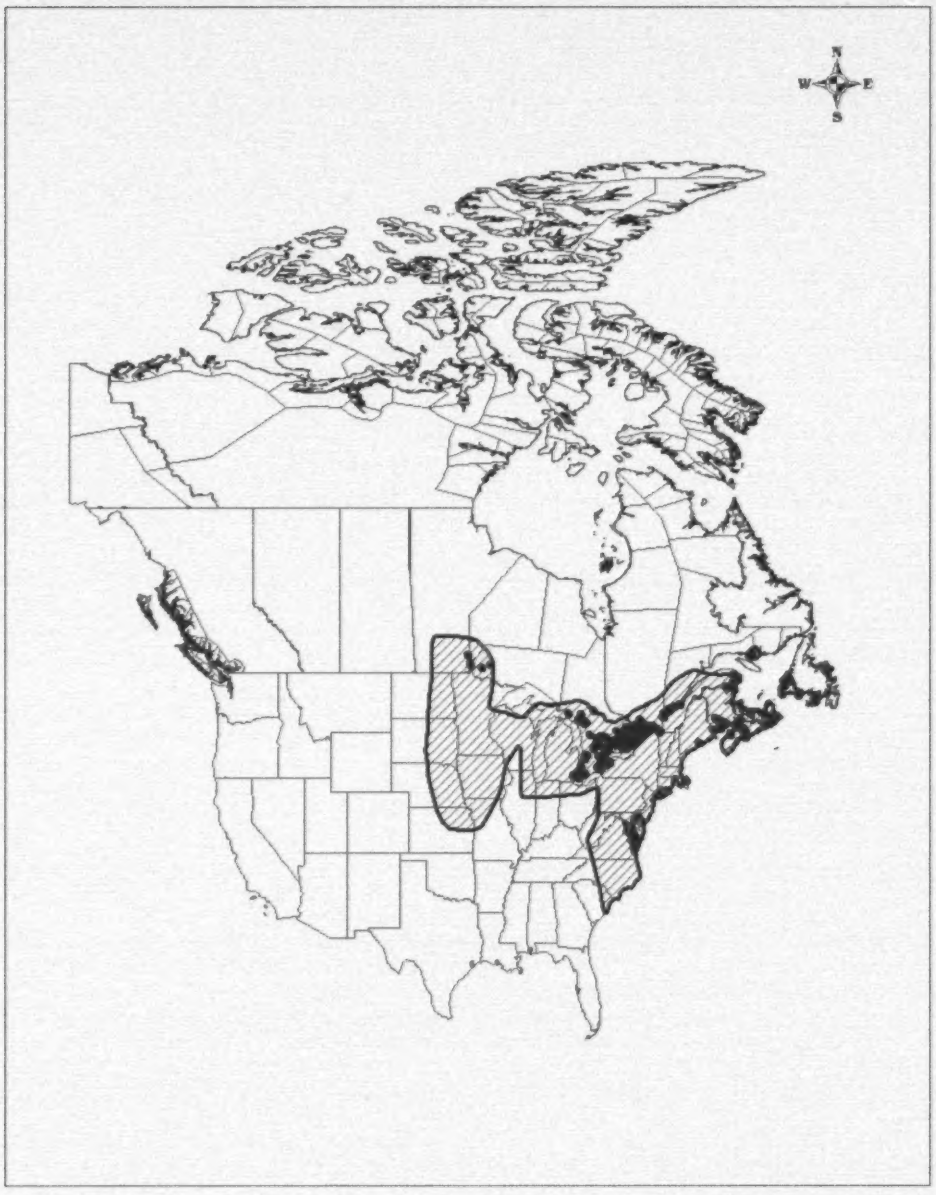

Figure 2. North American distribution of Banded Killifish (range taken from Scott and Crossman 1973 and Gilbert and Shute 1980; Actual population records from ROM data; Newfoundland additions from Chippett *In prep.*).

specimens were collected from the Red River, near Winnipeg in 1954 (Stewart-Hay 1954), and one other from the southwest arm of Crowduck Lake (50°05' N, 95°08' W) in the Winnipeg River system in 1985 (Stewart et al. 1985; K. Stewart pers. comm.). The most easterly population record is from the Indian Bay watershed on the northeast coast of Newfoundland (49°04'N, 54°06'W) (M. van Zyll de Jong, pers. comm.).

The status of this species in Canada was first considered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 1989. Newfoundland populations were considered to be biogeographically isolated from mainland populations and were assigned a status of Special Concern due to the limited area of occupancy, limitation of potential for range expansion and potential threats from logging and other activities leading to habitat degradation. Populations elsewhere in Canada were deemed to be not at risk at that time.

Newfoundland Range

The eastern Banded Killifish, *Fundulus diaphanus diaphanus* was known from only four localities in southwestern insular Newfoundland (ROM data; Scott and Crossman 1973). *F. d. diaphanus* was first reported from specimens taken in brackish water at the head of St. George's Bay, near Stephenville Crossing in 1951 (Templeman 1951). The distribution was then extended to include a freshwater lake, Loch Leven (48°10'N., 58°53'W.), 50 km to the south of Stephenville Crossing (Gibson et al. 1984) and Ramea Island located 7 km off the south coast of Newfoundland (Day 1993). The known range in Newfoundland was extended east to Freshwater Pond (47°06'N., 55°16' W.) on the Burin Peninsula on the south coast of Newfoundland, when four specimens were taken in 1984 (Gibson et. al 1984).

Throughout the 1990's *F. d. diaphanus* was reported in several freshwater lakes in the Indian Bay watershed on the north side of Bonavista Bay in northeastern Newfoundland. The first record of the eastern Banded Killifish from this area was July 1993 when a single specimen was taken from an open area over a rocky outcrop in Second Pond (Indian Bay Big Pond) (49°04'N, 54°06'W) (M. van Zyll de Jong, pers. comm.). No additional specimens were taken until July-August 1997 when 9 killifish were captured in experimental fyke nets in Backup (49°05'N, 54°11'W) and Third ponds (49°03'N, 54°12'W) in the same watershed (personal observations). This population is further east than the Freshwater Pond population reported by Gibson et al. (1984). An angler caught a large Banded Killifish in June 1999 in a pond in the town of Winterland (J. Yetman, pers. comm.), just a few kilometers from the Freshwater Pond population referenced by Gibson et al. (1984). An additional population at First Pond (47°35'N, 59°10'W) was discovered during an aquatic plant study by researchers of the Sir Wilfred Grenfell Campus of Memorial University in lakes on the west coast of Newfoundland in the Grand Bay West area (H. Mann, pers. comm.). Figure 3 indicates known Newfoundland populations of Banded Killifish and the years when these populations were discovered or recorded.

While there may be unrecorded populations in close proximity to existing records on the southwest coast, it is extremely unlikely, given the exploratory netting and observation performed in both National parks, the Great Northern Peninsula, Central Newfoundland, the Avalon Peninsula and areas surrounding the Indian Bay population, any new population records will be reported in these areas. Therefore, the extent of the distribution is likely a cluster of populations in the southwestern region with an outlier population in the Indian Bay watershed in the Bonavista North region.

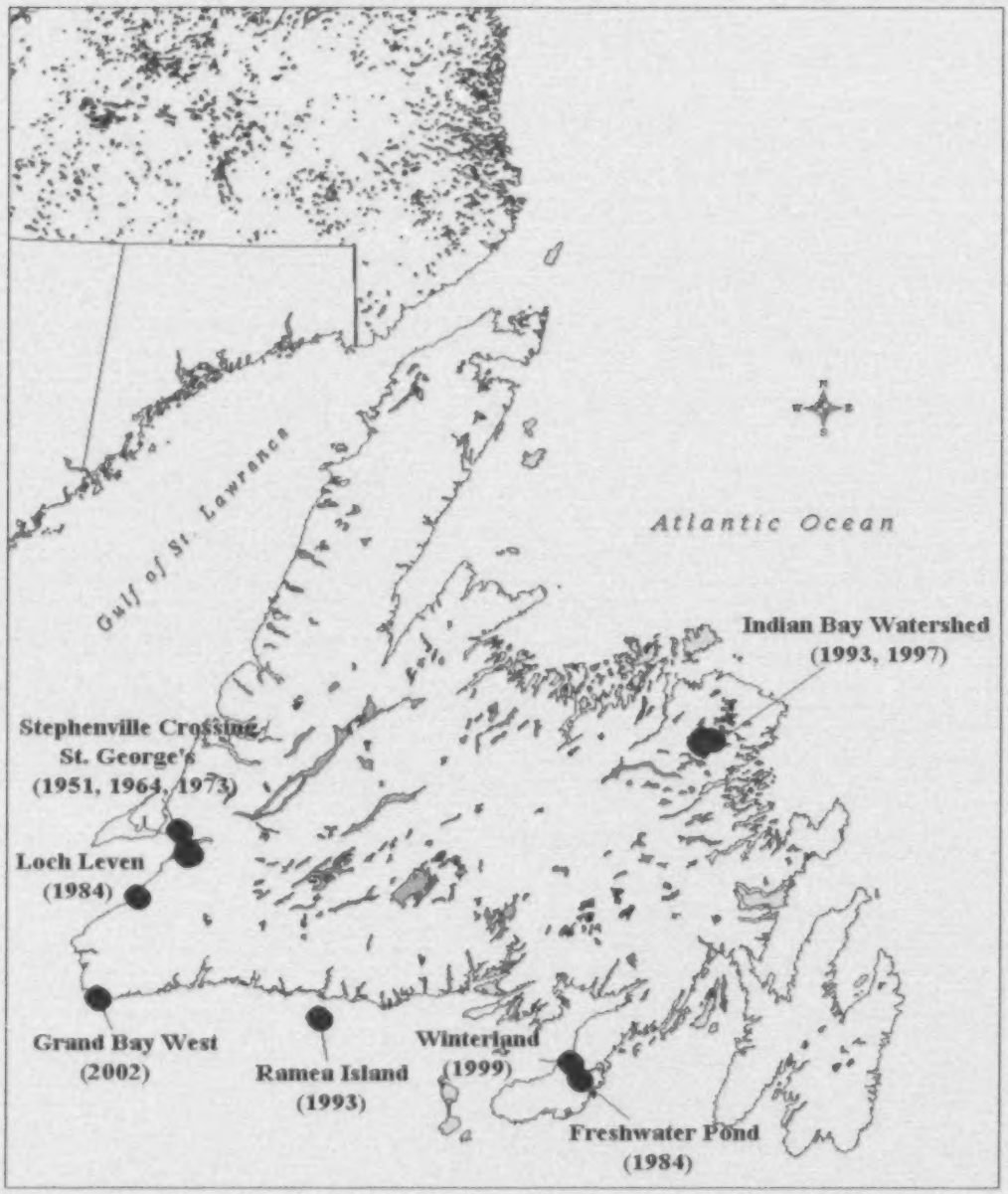

Figure 3. Newfoundland distribution of Banded Killifish (year of record in parentheses) (Chippett *In prep.*).

Other areas surveyed where Banded Killifish were not observed or caught included Notre Dame provincial park and Beothuk park (formerly provincial), Trinity Bay near Winterton, Mint Brook in the Gambo area, and all other lakes in the Indian Bay watershed. Other unsuccessful preliminary surveys were performed in various lakes in the Gros Morne National Park area in conjunction with Parks Canada and the Memorial University Bonne Bay Field Station (T. Knight, pers. comm.) and by Parks Canada staff and the author in the

Terra Nova National Park area (D. Cote, pers. comm.). Inland Fish (provincial department of Tourism, Culture, and Recreation) fyke netting programs on the Avalon Peninsula, the Millertown area in central Newfoundland, and on the Northern Peninsula in the Main Brook area have also failed to produce any new records of this species.

There is no conclusive information regarding the origin of the species on the island. Underhill (1986) provides an uncorroborated statement that the Banded Killifish have a marine origin from the Atlantic Provinces. However, he does not indicate by this, if this was a recent phenomenon, or if it related to population of the island following the last ice-age. Glaciation had a large impact on fish assemblages on the eastern coast of Canada due to glacial lakes/corridors etc., but the lineages of most species have yet to be determined. Researchers at the University of New Brunswick have recently begun to look at this issue and have hypothesized that the Banded Killifish may have evolved here after following the retreating ice sheets across the Gulf. They were then trapped in the freshwater lakes during uplift as the glaciers melted (A. Curry, pers. comm.). Underhill (1986) provides no evidence of migrations and there are no other occurrences in the literature to suggest or substantiate a supposition that such a small fish would be able to regularly migrate a passage of nearly 200 km across the Cabot Strait.

HABITAT

Habitat Requirements

As nearly all the literary accounts indicate, Banded Killifish are most often observed in the shallows and quiet areas of clear lakes and ponds with a muddy or sandy substrate, high detrital content, and abundant submerged aquatic vegetation (e.g. Trautman 1957; Scott and Crossman 1964, 1973; Houston 1990).

Qualitative examinations of lakes where Banded Killifish populations occur in Newfoundland are consistent with accounts describing Banded Killifish habitat. Dense submerged aquatic vegetation, in particular, and a variety of substrates ranging from fine sand and mud to gravel and cobble were good indicators of the regions where Banded Killifish were most often observed or caught (Chippett *In prep.*). The relationship between Banded Killifish and submerged aquatic vegetation is related to the plant-spawning behaviour of Banded Killifish and the need for vegetation for the adherence of eggs. Macrophytes common in areas where Banded Killifish exist in the Indian Bay watershed included *Utricularia purpurea, Potamogeton epihydrus, Myriophyllum tenellum, Lobelia dortmanna*, and *Eriocaulon* and *Isoetes sp.* with densities ranging from 4-16 per 0.25m^2 quadrants. The most predominant species are *Lobelia dortmanna*, *Isoetes sp.* and *Eriocaulon sp.* (Chippett *In prep.*).

Trends

Banded Killifish habitat, in terms of substrate type and aquatic vegetation, is readily available throughout most regions of Newfoundland (Chippett *In prep.*). Habitat is

limited only to the extent that it is unlikely to be utilized in more inland waters due to rivers of steep gradients and other barriers to migration. Moreover, Banded Killifish are often not observed in areas of suitable habitat in areas connected via passable streams to known populations. This is particularly evident in the Indian Bay watershed where Banded Killifish have been caught in only 3 of 17 lakes, but where appropriate habitat is found in various regions of all lakes (Chippett *In prep.*) and, for the most part, there do not appear to be barriers to migration.

Protection/Ownership

Houston (1990) indicated that there is no special protection for this species in Canada and that general protection is available through the habitat sections of the federal Fisheries Act. In August 2002, however, the Newfoundland and Labrador government passed an Endangered Species Act protecting *Fundulus diaphanus* and 19 other species. There are special circumstances surrounding certain populations including the potential of the Grand Bay West population (First pond) being included in an ecological reserve, the Winterland population being a part of the Eastern Joint Habitat Venture, and the closure of Loch Leven to recreational angling reducing public traffic in, on and around this lake. The presence of Banded Killifish in these areas, however, had little to do with these initiatives and was usually discovered after steps to protect the region had already been taken (Chippett *In prep.*).

In certain areas of the United States, Banded Killifish have disappeared from watersheds where they were traditionally known to occur. *Fundulus diaphanus* is considered endangered in Pennsylvania and South Dakota and have entered a period of decline in Illinois (Houston 1990). Protected status has been granted in South Dakota and Ohio in the latter a massive effort involving captive breeding and reintroduction has been developed with some success in reintroducing Banded Killifish to parts of its original range in that state. Much of the habitat concerns for Banded Killifish in the United States are due to habitat degradation and loss due to wetland drainage (Houston 1990).

BIOLOGY

General

Of the three Newfoundland populations sampled, the Loch Leven population had the largest mean total length at 91.9mm (56.5-106.3mm) while the Indian Bay population averaged 88.8mm (68.6-128.4mm) and Freshwater Pond population 73.2 mm (Chippett *In prep.*). In previous studies Banded Killifish adults usually ranged from 6-8cm (Cooper 1983). The 12.8cm record from Indian Bay is likely the largest recorded length for this species. Scott and Crossman (1973) indicated that a Banded Killifish measuring 11.4cm from Lake O'Law in Nova Scotia was the largest record prior to the Indian Bay record.

Carlander (1969) reported that individuals reach maturity at 1+ years and at a total length of about 6cm. The minimum size for mature females from the Newfoundland populations was noted to be 5.6cm (Chippett *In prep.*).

Reproduction

Banded Killifish are plant spawners and females release eggs attached to individual adhesive threads that adhere to aquatic vegetation once released. Males release milt and fertilize the eggs as they hang from the female papilla in clusters of 5-10 eggs (Richardson 1939). Spawning is indicated as taking place in April to May with a temperature of 21°C being preferred (Carlander 1969) while other spawning observations have been documented at 23°C (McAllister and Coad 1974).

Banded Killifish in the Indian Bay watershed were observed exhibiting spawning behaviour in late June through to the middle of August when water temperatures reached between 19-23°C, most often in association with pondweed species of the genus *Potamogeton*. Males undergo a drastic color change when spawning, developing a bright blue patch near the anal fin (Chippett *In prep.*; Scott and Crossman 1973). The lower portion of the body, including the area around the anal fin, transforms into a brilliant iridescent blue color. In areas where the water is dark or murky, particularly those with mud substrates like the Indian Bay watershed, the males can be identified by quick darting movements made obvious by the blue coloration against the dark substrate (Chippett *In prep.*). This color change is much more evident in the wild than in captivity.

Eggs taken from female fish in the Indian Bay watershed in late July were slightly larger ($\bar{x}$ = 2.2mm) than the 2.0mm reported by Cooper (1936) and large females contained as many as 420 eggs as compared to the 250 reported by Carlander (1969) (Chippett *In prep.*).

Physiology

Banded Killifish are tolerant of low oxygen levels and a wide range of temperatures (Scott and Crossman 1973; Houston 1990). Carlander (1969) observed Banded Killifish at 38.3°C while Rombough and Garside (1977) reported 34.5°C as the upper incipient temperature limit for this species. In Newfoundland, Banded Killifish spawning was observed at water temperatures of 22-24°C in the shallows and abundance of *Fundulus diaphanus* in fyke net catches was strongly related to water temperatures (Chippett *In prep*). These observations concur with those of Melisky et al. (1980) who found that Banded Killifish in Pennsylvania had a preference for waters of approximately 28.6°C and that fish in Nova Scotia prefer the lower temperature of 21.0°C. Banded Killifish move into deeper sections of lakes during late fall and winter before emerging into the shallows after the ice melts in April or May (J.G. Godin, pers. comm.).

Banded Killifish are euryhaline but usually inhabit freshwater streams and lakes, rarely existing in brackish or marine waters (Fritz and Garside 1974, 1975). This is true

of the Newfoundland populations (Chippett *In prep.*). *Fundulus diaphanus* is tolerant, however, of salinities in excess of 20ppt, making dispersal through salt water possible (Griffith 1974). Underhill (1986) states that the Banded Killifish may have a maritime origin from the Atlantic provinces, but as indicated above, this is debatable. The populations on the south and west coasts appear close enough to make migration between the Newfoundland populations possible, but, such movement is undoubtedly small in scale (Chippett *In prep.*). The population on the northeast coast in the Indian Bay watershed may have been the result of an introduction, as anecdotal evidence by local anglers suggests; anglers from the Maritime provinces using minnows (live-bait) have traditionally fished in Backup and Third Ponds (W. Norris, pers. comm.). It is common for both Banded Killifish and *Fundulus heteroclitus* to be sold as live-bait in Nova Scotia and New Brunswic (A. Curry, pers. comm.).

Movements/Dispersal

Banded Killifish were observed in shallow, sheltered areas during the day in areas with abundant, dense, submerged aquatic vegetation, with very little observed migration during the daylight hours. However, data from fyke nets set in a variety of habitat types indicated a greater abundance of killifish in deeper, more exposed rocky areas suggesting nocturnal movements away from and/or between vegetated areas (Chippett *In prep.*).

The Banded Killifish in the Indian Bay watershed occupy a very restricted range. It is likely that the species has had little success in dispersing throughout the watershed due to long stretches of deep, open water where brook trout and Atlantic salmon predation would be substantially higher than would be the case in the weedy shallows (Chippett *In prep.*).

Nutrition and Interspecific Interactions

Keast and Webb (1966) indicated that despite the superior position of the mouth, Banded Killifish feed in all levels of the water column. Smaller individuals eat chironomid larvae, ostracods, cladocerans, copepods, and small quantities of amphipods and some flying insects while larger individuals feed on the aforementioned species and also take Odonata and Ephemoptera nymphs, molluscs, tubellarians, and small crustaceans (Keast and Webb 1966; Baker-Dittus 1978). While specific information on Banded Killifish feeding is not available for Newfoundland populations, specimens taken from the Indian Bay watershed did contain a high proportion of chironomid larvae (personal observations).

Fundulus diaphanus is a forage fish for larger species like Atlantic salmon (*Salmo salar*), brook trout (*Salvelinus fontinalis*) and American eels (*Anguilla rostrata*) and is also preyed upon by Belted Kingfishers (*Megaceryle alcyon*) and American Mergansers (*Mergus merganser*) (White 1953,1957; Scott and Crossman 1973). However, adult Banded Killifish are often observed in association with large schools of young brook trout of similar size and are caught in fyke nets with brook trout, American Eels (*Anguilla*

rostrata),Three-spined Sticklebacks (*Gasterosteus aculeatus*), Atlantic Salmon adults and parr, and Rainbow Smelt (*Osmerus mordax*). Predation in Loch Leven is likely extremely high from the large population of American Eels in this area as indicated by the numbers in fyke net catches (Chippett *In prep.*).

Behaviour

Schooling

Banded Killifish adults (3-4 yrs) were usually observed in small schools of 3-6 individuals while younger fish (1-2+ yrs) were most often recorded in schools of 8-12 individuals. Schools remained in the same general area for long periods of time. Smaller fish use edges of areas of still water with abundant riparian vegetation for shelter while the adults (3-4 yrs) were found in more open areas, particularly at the outflows of streams and brooks (Chippett *In prep.*). Schooling likely plays a role in predator avoidance and feeding (Keast and Webb 1966; Godin and Morgan 1985).

Spawning

Banded Killifish in the Indian Bay watershed were observed exhibiting pre-spawning and spawning behaviour in late June through to the middle of August when water temperatures reached between 19-24°C (Chippett *In prep.*). As observed by Richardson (1939) males selected breeding areas in quiet weedy pools and defended these areas vigorously after which males and females of similar size paired off. The intense circling bouts between rival males were also observed to the extent of the pursued males being "forced" out of the water (personal observations).

POPULATION SIZES AND TRENDS

Population estimates have not been attempted with this species previous to the current research (Houston 1990). Schnabel mark-recapture estimates were performed in the Indian Bay watershed in July and August of 1999. Water temperatures were lower in July and likely contributed to an estimate of 1209 individuals (95% confidence limits 619-3423) whereas the August estimate was for 20,569 individuals (95% confidence limits 12,529-40,201). The relationship between temperature and killifish abundance in fyke net catches in three study sites between 1999-2001 was significant when the data are log transformed with a p-value of 0.000 (Figure 4) (R-sq=0.190, F-ratio=11.776, ss=45). Any future investigation of population size would best be performed in late July and through August when water temperatures are higher and killifish abundance and activity are at their highest levels (Chippett *In prep.*). Figure 4 indicates the relationship between water temperature and catch per unit effort of Banded Killifish in three Newfoundland lakes. In the absence of additional estimates, these data do not provide suitable information on population trends, but merely describe the condition of the Indian Bay population in 1999.

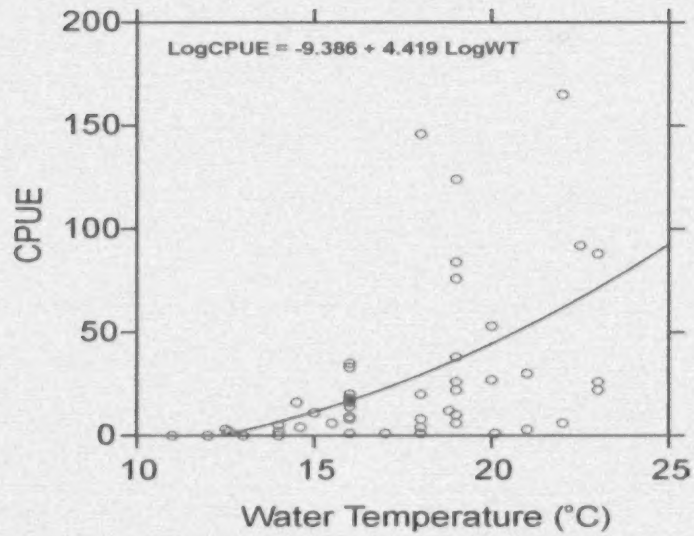

Figure 4. Relationship between Banded Killifish catch per unit effort and water temperature in three Newfoundland lakes (Loch Leven, Third Pond (Indian Bay Watershed), and Freshwater Pond) (Chippett *In prep.*).

The catch per unit effort (CPUE) values presented in Table 1 are much higher for the Indian Bay watershed than for the Loch Leven and Freshwater Pond populations. The species is so restricted in distribution in the Indian Bay watershed that nets were always placed in areas where Banded Killifish were known to occur based on prior experience. As a result, the Indian Bay sampling may have targeted areas with greater numbers of Banded Killifish in the area. However, in the other populations, particularly Freshwater Pond, the range of the species is larger and individual fish would be found throughout a larger area making sampling site selection a factor. The large CPUE's and the maximum numbers of killifish caught in fyke nets in July and August indicate that this species is locally abundant at Loch Leven, Freshwater Pond and Indian Bay, which is in agreement with Houston (1990). In Third Pond, in the Indian Bay watershed, Banded Killifish numbers reached maximums of nearly 200 killifish per net in late July and early August (Figure 4). At Loch Leven, large schools of Banded Killifish of approximately 25-40 individuals are easily observed in the sandy shallows, particularly on warm sunny days (personal observations). The size and movements of these schools in the shallows create the illusion of "bubbling" or "boiling" water as described by Gilhen (1974).

Table 1: Mean catch per unit effort (CPUE – individuals/set) values for three representative Newfoundland Banded Killifish populations (Chippett *In prep.*).

Population	# of net sets	$\bar{x}$ CPUE (Catch per Unit Effort)
Indian Bay	24	42
Loch Leven	10	29
Freshwater Pond	10	23

LIMITING FACTORS AND THREATS

There are two limiting factors to be considered with respect to Banded Killifish populations in Newfoundland. These are forestry activity (or any other potential anthropogenic disturbance) and the potential impacts of forestry on freshwater watersheds inhabited by this species, and obstacles, such as steep river gradients and physical barriers, preventing inland migration and access to additional suitable habitat.

While little in the way of clear cutting is occurring on the west coast in the area around Banded Killifish populations (H. Smith, pers. comm.), much of the area surrounding several lakes in the Indian Bay watershed, particularly around Fourth Pond, directly connected to Third Pond, one of the lakes containing Banded Killifish, has been or is planned to be clear cut over the next 5 years (M. Wells, pers. comm.). Wells (2002) indicated statistically significant sediment accumulation increase for a 20 m buffer with selective harvesting within the Indian Bay watershed along a headwater stream ($p=0.0172$ for sediment > 1mm in diameter, 4-fold increase, $p=0.0001$ for sediment < 1mm in diameter, 5-fold). The effects of such increased suspended sediments include reductions in invertebrate abundances, decreased feeding success for sight feeding species, and dislocation and mortality of early life stages (Miller 1981). Sediments can also abrade and suffocate periphyton and macrophytes thus decreasing the primary production (Waters 1995). Desgagne and Lalancette (1984) indicated that Banded Killifish feed based on visual perception and as Richardson (1939) stated Banded Killifish make use of macrophytes in their reproductive cycle. Therefore these developments may have a severe impact on Banded Killifish populations in Indian Bay should this phenomenon occur throughout the watershed.

Despite the broadened distribution since the previous status report, the newest records are coastal in nature, likely confirming that migration inland is restricted by steep river gradients and impassable rapids or falls. This fact will likely mean that future discoveries will be coastal in nature and that further inland discoveries will be highly unlikely.

Other suggested limiting factors such as low water temperatures and the availability of suitable habitat (Gibson et al. 1984; Houston 1990) are probably not limiting to Banded Killifish in Newfoundland. Shallow regions in all population locales surveyed reached upper temperature limits of at least 23°C in July and August meaning that spawning should have been easily accomplished in these areas. However, in areas where Banded Killifish were restricted in distribution to one or two lakes, abundant suitable habitat in other lakes linked by easily passable brooks and streams showed no evidence of Banded Killifish presence. This trend is evident in several of the watersheds where populations occur and indicates a more detailed study of potential habitat parameters is required.

SPECIAL SIGNIFICANCE OF THE SPECIES

Fundulus diaphanus is one of two cyprinodontid species in Newfoundland, the other being the mummichog, the closely related *F. heteroclitus*. As stated earlier Banded Killifish are considered a forage fish for brook trout and Atlantic salmon and are used as a bait fish in certain parts of North America (Houston 1990).

The populations of Banded Killifish in Newfoundland are at the eastern extent of the complete North American range of this species and are clustered in a fairly confined geographical area, with the exception of the Indian Bay population. This distribution of Banded Killifish might make it an ideal indicator species for development or industry in these areas that may impact upon freshwater ecosystems. The research contributing to this status report has helped to raise awareness of this species in Newfoundland and to synthesize much of the independent work being conducted on this species. The Banded Killifish is currently the subject of proposals by Parks Canada and the Eastern Habitat Joint Venture that will look at habitat selection and use in greater detail and the potential of artificial substrate utilization. It is recognized in the Winterland ecomuseum, an interpretive boardwalk through wetland and barrens on the Burin Peninsula, as a species existing in the Rush Ponds, and needing the muddy and densely-vegetated habitat these waterbodies provide. The most recently documented population is in the Grand Bay West area, where the Government of Newfoundland and Labrador is in the process of creating an ecological reserve.

EXISTING PROTECTION OR OTHER STATUS

The Newfoundland populations of Banded Killifish, *Fundulus diaphanus*, were designated as vulnerable (species of special concern) by the Committee on the Status of Endangered Wildlife in Canada in 1989 (Houston 1990). More recently, a new Endangered Species Act passed by the Newfoundland and Labrador provincial government in August 2002 lists *F. diaphanus* as one of 20 species protected under this Act. Houston 1990 indicated that Manitoba populations are considered of special concern while this species has an endangered status in the states of Pennsylvania and South Dakota. Since this report, the Manitoba Conservation Data Centre has ranked the Banded Killifish as G5, S1 (Stewart, pers. comm.). The only other specific protection afforded Banded Killifish in Canada is through the Federal Fisheries Act, which prohibits the destruction of fish habitat.

SUMMARY OF STATUS REPORT

The Newfoundland populations of Banded Killifish, *Fundulus diaphanus*, were designated as vulnerable (species of special concern) by the Committee on the Status of Endangered Wildlife in Canada in 1989 (Houston 1990). This updated report recommends that this species be evaluated based on the following conclusions.

Banded Killifish populations in Newfoundland are very restricted in nature. In spite of 7 known population locales, the area of occurrence of these populations is less than 200 km^2. In addition, these populations, with the exception of the Indian Bay watershed population, are clustered in relatively close proximity on the southwestern portion of Newfoundland, maximizing the potential of natural disturbance, urban expansion, and industrial development, on 4 of the 7 recognized Newfoundland locales.

The most likely limiting factor impacting *F. diaphanus* in Newfoundland is rivers with steep gradients and other obstructions to migration. This geographic feature will restrict this species to the coastal regions where it has been discovered thus far and prevent dispersal throughout the central insular waters of Newfoundland. Therefore, although appropriate habitat is abundant in these regions, much of it is inaccessible to Banded Killifish due to difficult migration routes.

The obvious habitat requirements associated with Banded Killifish throughout North America, which include dense submerged aquatic vegetation, muddy or sandy substrates, and warm water temperatures for spawning, are not limiting factors in Newfoundland. However, even in coastal watersheds that include easily passable linkages between several lakes with much habitat as described previously, Banded Killifish still remain restricted in one "isolated" geographical pocket population and do not appear to spread throughout the entire system. More information is required on the strict parameters surrounding habitat selection and use and the dispersal of Banded Killifish throughout watersheds in Newfoundland and this should be a priority for any future research on this species in Newfoundland.

TECHNICAL SUMMARY

Fundulus diaphanus
Common name: Banded Killifish, Swimp (NF name) (English) ***Fondule barre*** (French)
Range of occurrence in Canada: Newfoundland Population (also occurs in MB, ON, QC, PE, NB, NS)

Extent and Area Information	
• extent of occurrence (EO – in Newfoundland	< 50,000 km²
• trend	Unkown
• are there extreme fluctuations in EO (> 1 order of magnitude)?	No
• area of occupancy (AO)	< 200 (km²)
• trend	Stable
• are there extreme fluctuations in AO (> 1 order magnitude)?	No
• number of extant locations	7
• trend in # locations	Stable
• are there extreme fluctuations in # locations (>1 order of magnitude)?	No
• habitat trend: (in area, extent or quality of habitat)	Stable (only accessible in coastal regions)
Population Information	
• generation time (average age of parents in the population)	Mature at 1+ years
• number of mature individuals (capable of reproduction) in the Canadian population	Not Known
• total population trend	Unknown
• are there extreme fluctuations in number of mature individuals (> 1 order of magnitude)?	Unknown
• is the total population severely fragmented (most individuals found within small and relatively isolated (geographically or otherwise) populations between which there is little exchange, i.e., ≤ 1 successful migrant / year)?	Yes
• list of each population and the number of mature individuals in each	Indian Bay -1209-20569 Loch Leven - Unknown Stephenville Crossing - Unknown Ramea Island - Unknown Winterland - Unknown Freshwater Pond - Unknown Grand Bay West - Unknown
• trend in number of populations	Stable
• are there extreme fluctuations in number of populations (>1 order of magnitude)?	No
Threats	
Populations may be impacted by increased sedimentation resulting from logging, particularly in the Indian Bay area. Populations would be vulnerable to any disturbance impacting on water quality or macrophyte communities due to their restricted ranges and close proximity to one another.	
Rescue Effect	Unlikely
• does species exist elsewhere (in Canada or outside)?	Yes
• status of the outside population(s)?	Secure in Canada with the possible exception of Manitoba and Quebec. Nearest US populations are secure
• *(see existing status below)*	
• is immigration known or possible?	Unlikely
• would immigrants be adapted to survive here?	Yes
• is there sufficient habitat for immigrants here?	Uncertain
Quantitative Analysis	Not Available

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Jamie Chippett B.Sc.(hons.) is a M.Sc. student working under the supervision of Dr. Richard Haedrich at Memorial University of Newfoundland (MUN) where Jamie also is affiliated with the Coasts Under Stress research program. His research, that contributed to this update on the status of Banded Killifish in Newfoundland, will also form the basis for his Masters' thesis on the distribution, life history and evolutionary relationships of *Fundulus diaphanus* in Newfoundland. His undergraduate biology degree, also completed at MUN, included a specialization in entomology and parasitology. In the last 2 years, Jamie has completed a youth internship program with the Department of Fisheries and Oceans and the Indian Bay Ecosystem Corporation involving the classification of invertebrate fauna in a headwater stream of that ecosystem and was also employed as the Staff Biologist at the Quidi Vidi Rennies River Development Foundation (The Fluvarium), where he was responsible for a modular incubation unit for Atlantic salmon and coordinated the City Rivers Salmon Enhancement Program designed to reintroduce Atlantic salmon fry into St. John's city river systems.

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